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# TESTING FOR CORONA IN COAXIAL CABLES

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U. S. ARMY SIGNAL RESEARCH AND DEVELOPMENT LABORATORY
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**ABSTRACT**

This report supplements the information for corona testing of coaxial cables for Specification MIL-C-17C. The test circuitry and the calibration of the equipment are discussed to serve as a guide to cable manufacturers for such testing. The cable specimen preparation is also discussed to ensure corona free cable specimens. A brief discussion of the discharges within coaxial cables under high voltage stress is included.

## CONTENTS

# TESTING FOR CORONA IN COAXIAL CABLES

## INTRODUCTION

Premature breakdown of insulations under high voltage stresses has been traced many times to ionization of voids within the dielectric of the cables. To combat such failures, several methods have been developed over the years to determine the safe limits of operation of such cables. Naturally, one of the most desirable requirements of such a method is that it should be non-destructive. A test for corona has been used extensively in the past; however, the lack of a standard test procedure and calibration method resulted in significant variations of data from one laboratory to another as well as the possibility of bad cable passing the test.

Manufacturers of corona equipments have long been supplying the cable industry with suitable type equipments; however, the calibration level and the level of sensitivity at which the test was to be conducted was not defined. At the last Government-Industry meeting of MIL-C-17, this Laboratory recommended the use of 5 micromicrocoulombs as the level of sensitivity to be used for testing for corona in radio-frequency cables and USASRDL was subsequently requested to prepare this document.

This report will endeavor to serve as a guide for the performance and calibration of this test. It is not intended to discuss all the basic problems and detailed theory of corona phenomena. A comprehensive study is presently being conducted by this Laboratory to determine the modes and mechanism of failures of radio-frequency cables under high voltage ac stresses and the correlation between the discharges within a cable and its life characteristics. Upon completion of this study, the findings will be published.

## DISCUSSION

### *Theory*

The modes and mechanisms of corona in different insulations have been described in numerous papers. No attempt will be made at this time to discuss the detailed theory of corona in coaxial cables, since it is considered beyond the scope of this report. In brief, however, the mechanism of corona in a coaxial cable may be represented schematically as follows:

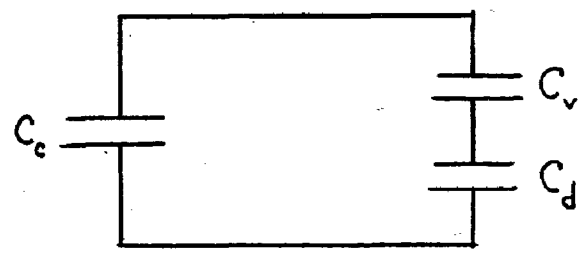



**Figure 1**

where $C_c$ = capacitance of cable

$C_v$ = capacitance of void

$C_d$ = capacitance of dielectric in series with $C_v$

When the voltage stress limit of the void is exceeded as a result of a sufficient large voltage applied to the cable, complete electrical breakdown will occur in the void. The duration of this discharge is in the order of $10^{-8}$ seconds and the components of the surge voltage may be

detected at frequencies up to 100 megacycles. Referring to Figure 1, when the discharge occurs, the voltage across $C_v$ falls by $\Delta V_v$. If $C_d << C_c$, the voltage across $C_d$ will increase by $\Delta V_v$, and the voltage across $C_c$ will decrease by $\Delta V_o$ or

$$q = C_c\ (\Delta V_c) = C_d\ (\Delta V_v)$$

which states that the capacitor $C_c$ suffers a loss of charge q. Therefore, the sensitivity of detecting the discharges is a function of $C_c$, the total cable capacitance and such sensitivity must be increased for large values of specimen capacitance.

*Test Method*

One of the methods used extensively is the resonant-circuit method of detection. This method offers excellent sensitivity and may be used to determine the size of discharges. The schematic diagram of this method is illustrated in Figure 2.

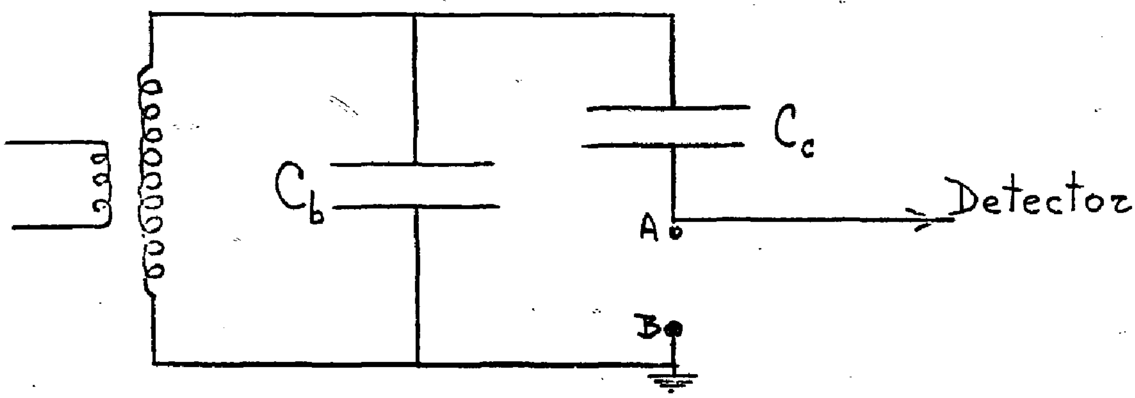
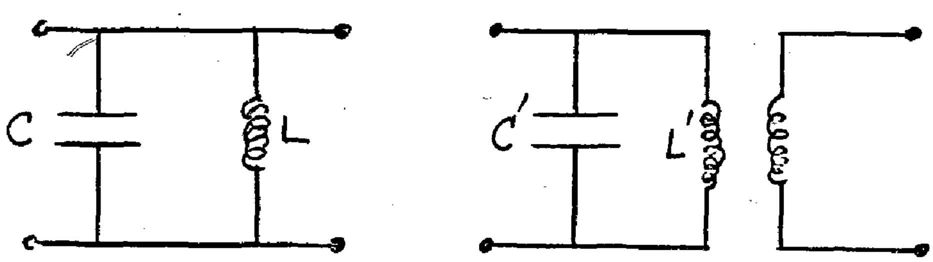



Figure 2

where $C_c$ = capacitance of cable specimen

$C_b$ = capacitance of coupling capacitor which must be corona free at the test voltage

Means must be provided at terminals A and B to reject the applied high voltage and serve for connection to the amplifier. There are several coupling devices that may be used; however, maximum sensitivity has been obtained by the use of a tuned circuit. The simplest form of such a circuit to be used would be the parallel combination of L and C (inductor coupling) with a resonant frequency in the neighborhood of 100 kc and 1 megacycle. An alternate circuit to be considered is transformer coupling. Both circuits are illustrated in Figure 3 respectively.




(a) Inductor Coupling

(b) Transformer Coupling

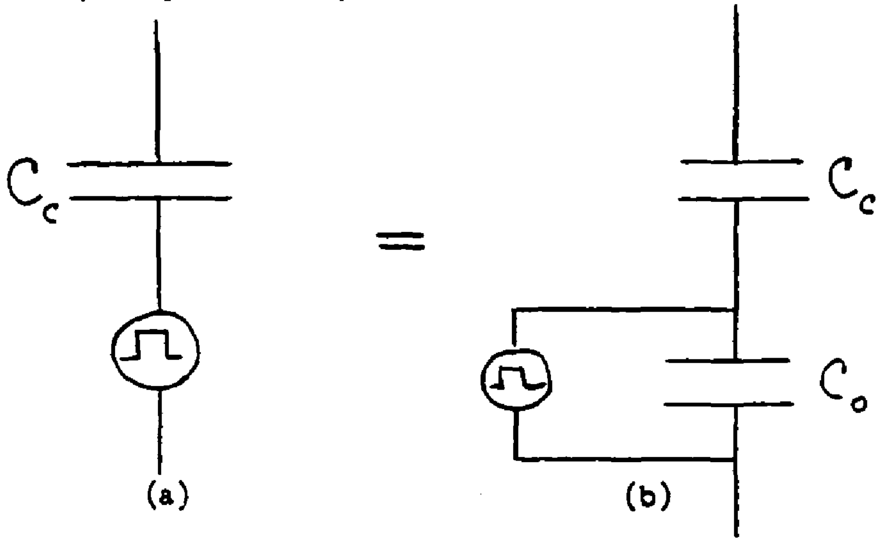
Figure 3

The coupling device connects to the input of an amplifier which has a gain consistent with the capacitance of the test specimens. If the capacitance is of the order of 100 mmfd, then the signal produced by a corona discharge of 5 micromicrocoulombs will be between 15 and 50 millivolts and the amplifier of an ascilloscope with 15 mv/inch sensitivity at the resonant frequency will be adequate. If the specimen is a length of cable with a capacitance of 30,000 mmfd, for example, the signal produced by a 5 micromicrocoulomb discharge will be between 15 and 156 microvolts and a preamplifier with a gain of about 300 at the resonant frequency will be needed between the coupling device and the oscilloscope.

One example is offered, in case the reader desires to construct his own corona test set. Condenser $C_b$ may have a value of capacitance larger than 1,000 mmfds and must be corona free at the test voltage. Utilizing inductor coupling, L is an RF choke with a value of 10 mh, and C, which includes the distributed capacitance, is 200 mmfd to yield a resonant frequency in the neighborhood of 100 kc. It should be noted that alternate circuits exist to that of Figure 2. One variation of this circuit is where the cable specimen is placed across the secondary of the transformer and a blocking capacitor in series with the tuned circuit. The value of the latter may be in the neighborhood of 100 mmfd.

*Calibration*

It has been shown that when a discharge occurs within the cable, a redistribution of electric charges occurs which changes the voltage across the terminals of the specimen. Consequently, the cable specimen may be considered equivalent to the capacitance of the specimen in series with a low impedance pulse generator, Figure 4a, which is in turn, equivalent




where $C_o$ is a coupling capacitor

Figure 4

to Figure 4b where $C_o >> C_c$. All stray capacitances should be kept to a minimum as they affect the sensitivity.

The calibration is performed as shown in Figure 5.

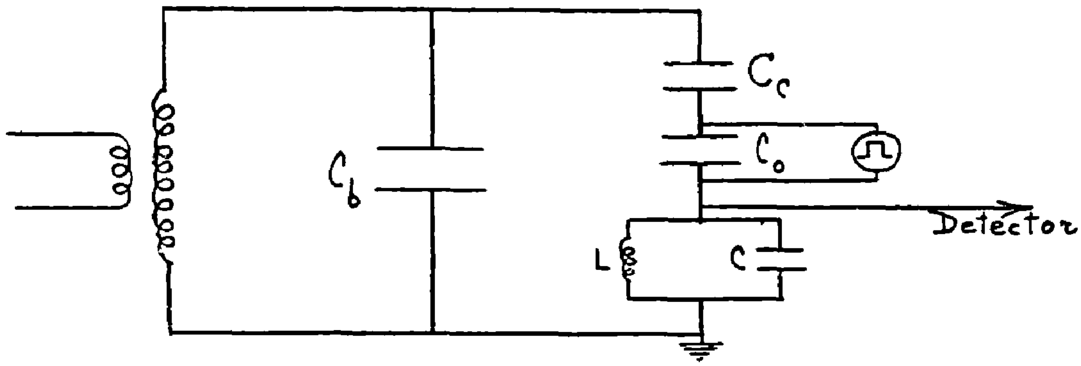



Figure 5

The capacitance of the cable specimen should be accurately measured. The cable specimen is then charged to a voltage $\Delta V_c$ sufficient to provide a mininum charge of 5 micromicrocoulombs; the specimen is then discharged into the resonant circuit with the resulting deflection observed on the oscilloscope. This deflection should be at least 1/2 inch in order to provide good accuracy. The repetition rate of the pulse generator should be approximately 100 pulses per second. The duration of the pulse should be 10 microseconds or longer and a rise time of 0.1 microseconds or less. The output-impedance of the generator should be 100 ohms or less. The loss of charge is then calculated by

$$\text{micromicrocoulombs per inch deflection} = \frac{C_c(\Delta V_c)}{\text{inches of deflection}}$$

where $C_c$ is in micromicrofarads

and $\Delta V_c$ in volts

An alternate method for the calibration is by utilizing the circuit of Figure 6.

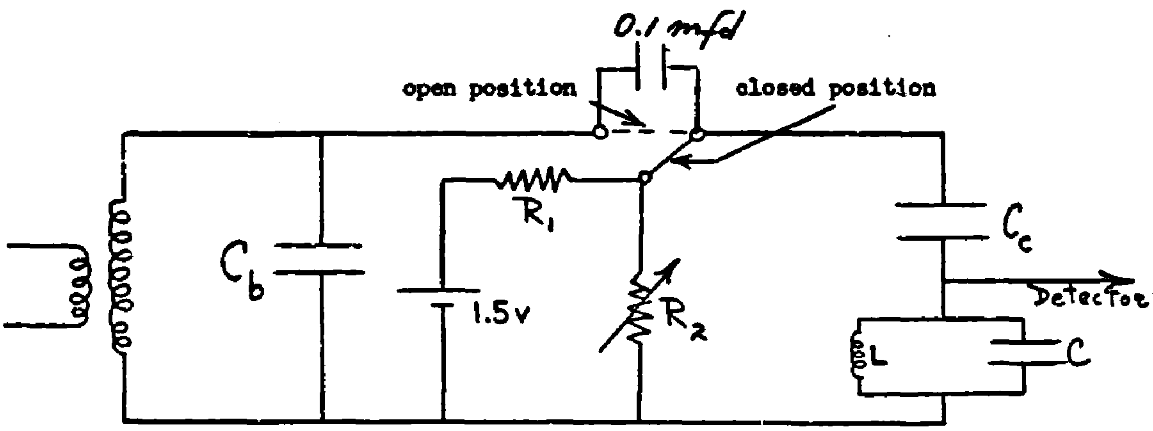



Figure 6

where $R_1$ = 10,000 ohms

and $R_2$ = decade box (10,000 ohms)

With the switch in the closed position, the cable specimen is charged to a voltage V. When the switch is opened, the specimen discharges into the resonant circuit and a deflection is observed on the oscilloscope. The loss of charge is the same as described in the previous method.

*Specimen Preparation*

The preparation of the cable specimens for corona testing is of paramount importance. If discharges occur at the terminations of the specimen, the corona extinction voltage of such specimen does not reflect the inherent cable performance and rejections of cable may result. Consequently, for the proper testing of the cable and his own protection, the manufacturer should make sure that the terminations of the samples are corona free.

A satisfactory method which is not considered time consuming and is economical, is described for use in corona testing of coaxial cables. The length of the specimen as required by the specification should be approximately 3 feet, excluding the terminations. A recommended length including terminations should be approximately 3-1/2 feet. This length may be increased for the large cables where higher voltages are encountered to eliminate any discharges at the terminations. Figure 7 illustrates the specimen preparation. After the specimen is prepared the ends are dipped into an insulating oil to immerse the exposed braid about 1/4" below the oil surface. Air bubbles should be carefully excluded from the end of the braid under oil. Connection to the inner conductor should be made in a way which allows adequate separation from the braid.

There are several precautions to be exercised during test.

1. Do not allow the tape to be applied over the dielectric of the cable. This will form voids and yield low corona extinction voltages.

2. It has been noted that several manufacturers make the ground connection in the middle of the sample by removing a section of the jacket and wrapping several turns of wire. Care should be taken to wrap such wire tightly because when the jacket is removed the braid tends to be loose.

## CONCLUSIONS

A method has been described for conducting corona tests on coaxial cables; it is known as the resonant circuit method. It should be noted that several other methods exist which may be used to conduct these tests; however, prior to acceptance proof of their sensitivity should be submitted.

Every corona test equipment should be checked periodically to determine its corona extinction voltage. The connections in the equipment should be tight and grounding at one point is recommended. No sharp points should be exposed to high voltage stress and access to the high voltage terminals should be made difficult, if not impossible, for the safety of the attending personnel.

The user of coaxial cables who anticipates using such cable under high voltage conditions should take precautions to ensure that no harmful discharges are present within the cable or its connectors during operation. If such discharges are present, premature breakdown of the system will occur. The ideal method for corona testing would be to test reels of coaxial cable. In view of the total capacitance of the reel, however, very sensitive and expensive equipments are required. Even if such equipment is used, unfortunately no method is presently available for locating the points of discharges in a finished cable. Several manufacturers of high voltage cable check the core of the cable which at least ensures that no voids are present between the inner conductor and the dielectric or within the dielectric.

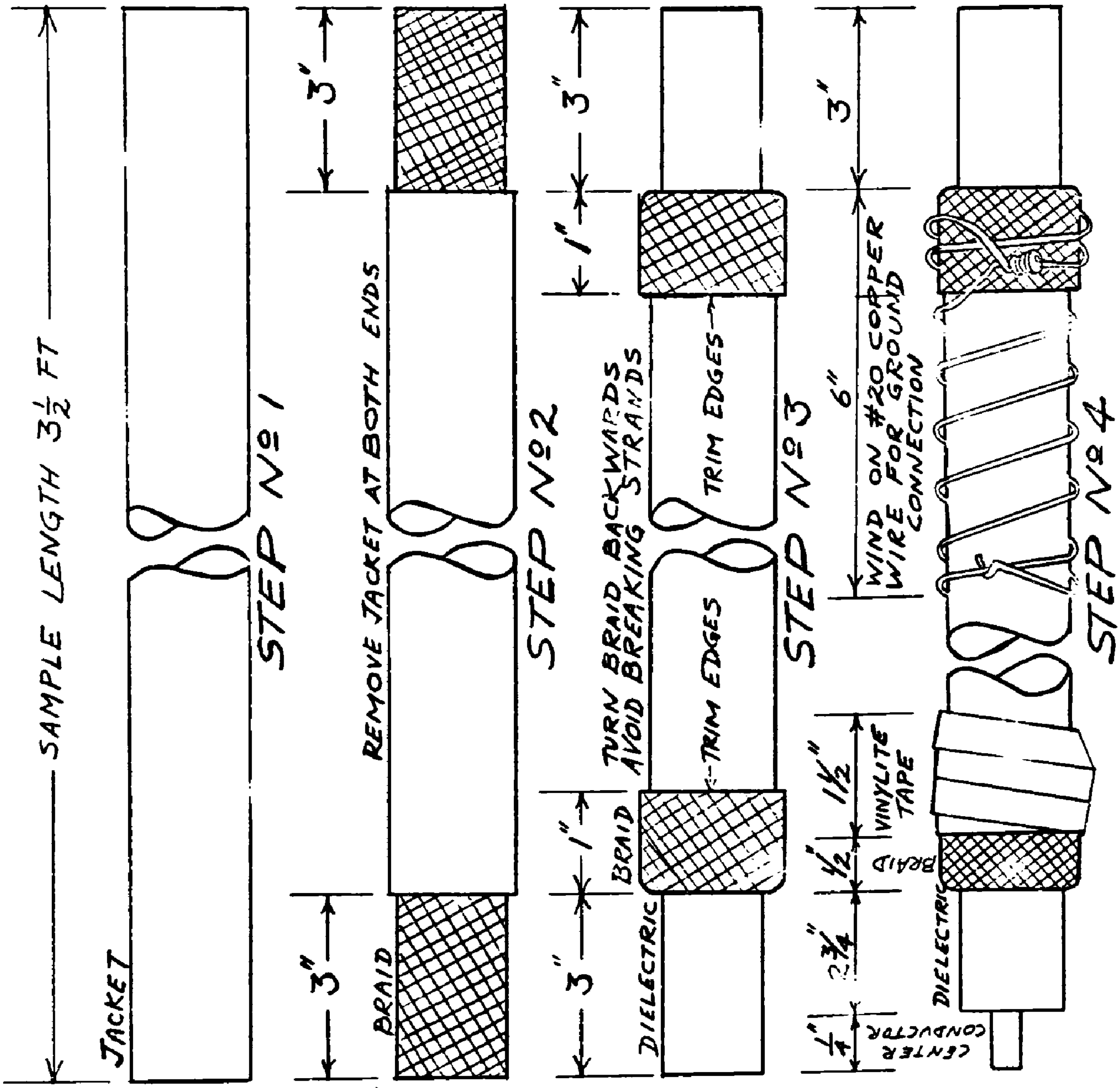



Fig 7. Cable Specimen Preparation

## RECOMMENDATIONS

It is recommended that the test and calibrating methods described herein be adapted by the Services for corona testing of coaxial cables. Such an action would enable interested personnel to compare corona results from several manufacturers and to ensure that manufacturers are meeting the same requirements.


## ACKNOWLEDGEMENT

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